Plasmonic Routes to Nanophotonics

Scientific Accomplishment

We have demonstrated that surface plasmons (SPs) can be focused into an intense, sub-wavelength spot. SPs are electromagnetic waves confined to the surface of metals or semiconductors and are the key element for extending the power of photonics to the nano-scale, well beyond the diffraction limit encountered in conventional optics. In our recent study (Nano Letters **5**, 1399 (2005)) we utilize the coherent superposition of SPs generated in a nano-structured metal film to focus the SPs and launch them onto sub-wavelength strip waveguides.

Surface plasmons open broad new horizons for for advancing our basic understanding of confinement and transfer of electro-magnetic energy at the nano-meter scale. Using near-field scanning microscopy (NSOM), we demonstrate constructive interference of surface plasmons launched from an array of 200-nm nanoholes placed on a 5 µm diameter quarter circle on Ag/Cr/glass multilayers. Coherent superposition produces a high intensity spot at the center of the circle confined to sub-wavelength transverse dimensions. The electric field in this spot is strong enough to induce non-linear optical phenomena needed for photonic logic and for enhanced optical spectroscopy of adsorbed molecules. We demonstrate propagation of surface plasmons along a guide composed of a 250 nm wide metallic Ag strip for a distance of 4 µm.

Significance

The photon has the potential to replace the electron as the ultimate processor of information. All-optical information technologies would enable profound advances in speed, bandwidth, and reduced power dissipation. Achieving these advances requires reducing the size of photonic components below the diffraction limit, and creating intense electric fields capable of inducing the non-linear optical phenomena needed for amplification and switching. Our advances in sub-wavelength focusing of surface plasmons by coherent superposition and in propagation of surface plasmons along confined metal nanostrips shows that these key requirements for all-optical information processing are within reach.

The intense electric fields we generate enable high sensitivity optical spectroscopy of single molecules and molecular assemblies. Unlike surface enhanced Raman spectroscopy (SERS), where intense electric fields are generated by high curvature at the surfaces of nanoparticles, our technique produces intense electric fields on a *smooth* surface where the relative orientation of adsorbed species and the incident electric field and propagation direction can be precisely controlled. This feature promises to extend the power and flexibility of high intensity optical spectroscopy to smaller molecules with controlled scattering geometries.

Performers

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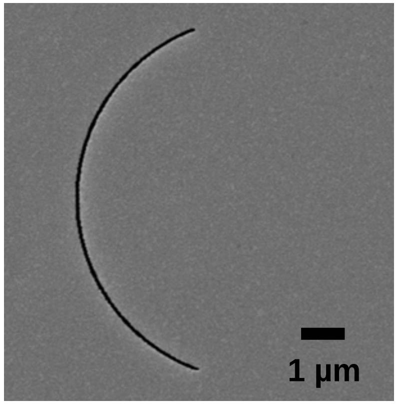
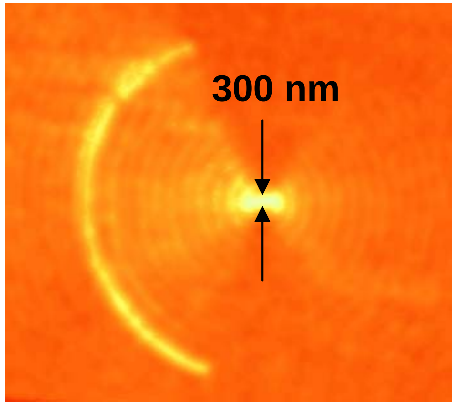


75-nm Ag-film
140 nm nano-slit



surface plasmon
interference, λ_{SP} = 506 nm

Launching of surface plasmons at nano-slits and nano-holes

Coherent superposition of SPP sources for sub-wavelength focusing

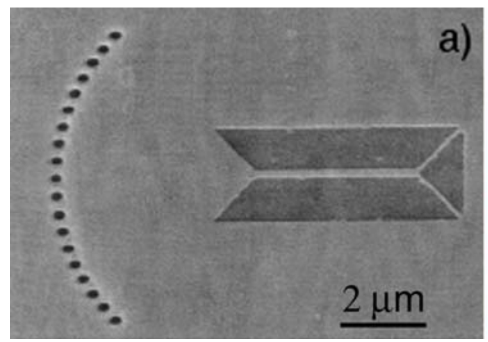
design arbitrary intensity patterns

high intensity for non-linear optics

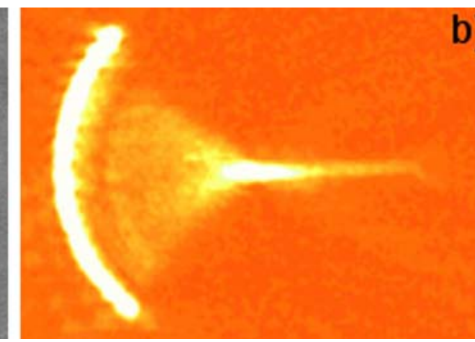
Sub-wavelength guiding of SPP on metal nano-strips

nanoscale photonic communication and logic

ultra-high speed, low dissipation



Ag nanostrip guide
250 nm wide 50 nm thick
4 µm long



guided propagation of
surface plasmons

Future: Incorporate active elements, all-optical switching

QDs, nanoparticles, dyes

Novel low-loss hybrid structures

L. Yin et al., Nano Letters **5,** 1399 (2005)

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